

SUPPLEMENTARY MATERIAL TO
**Modification of natural clinoptilolite and ZSM-5 with different
oxides and a study of the obtained products in lignin pyrolysis**

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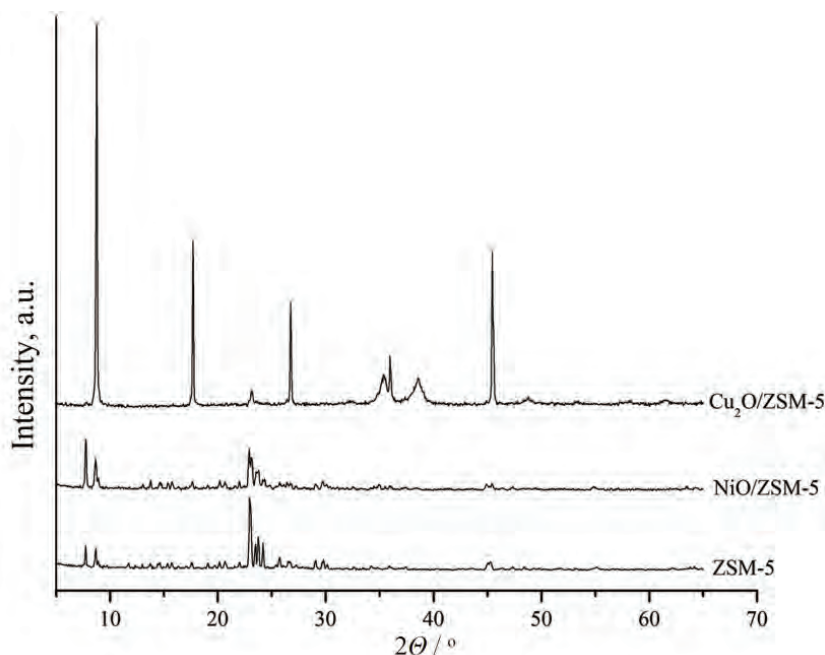


Fig. S-1. XRD patterns of ZSM-5, NiO/ZSM-5 and Cu₂O/ZSM-5.

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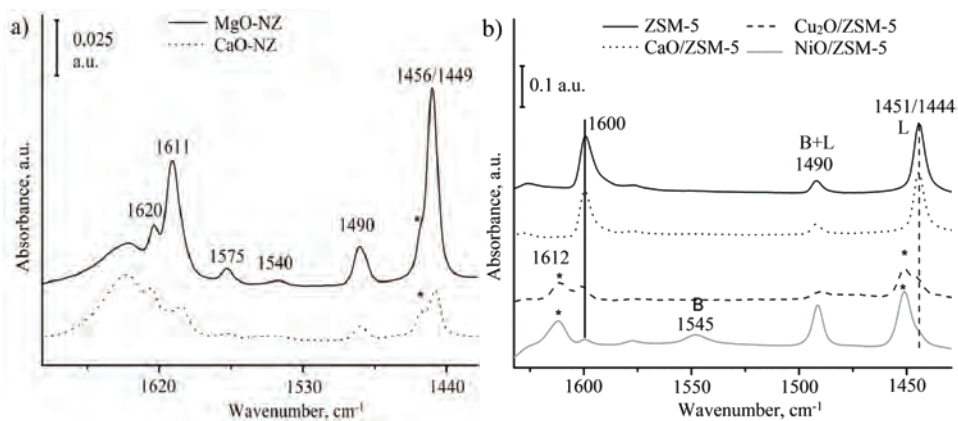


Fig. S-2. FTIR spectra of: a) NZ and b) ZSM-5 samples after pyridine adsorption. B – pyridine adsorbed on Brönsted sites, L – pyridine adsorbed on Lewis sites, B+L – common bands. * – distinct Lewis sites.

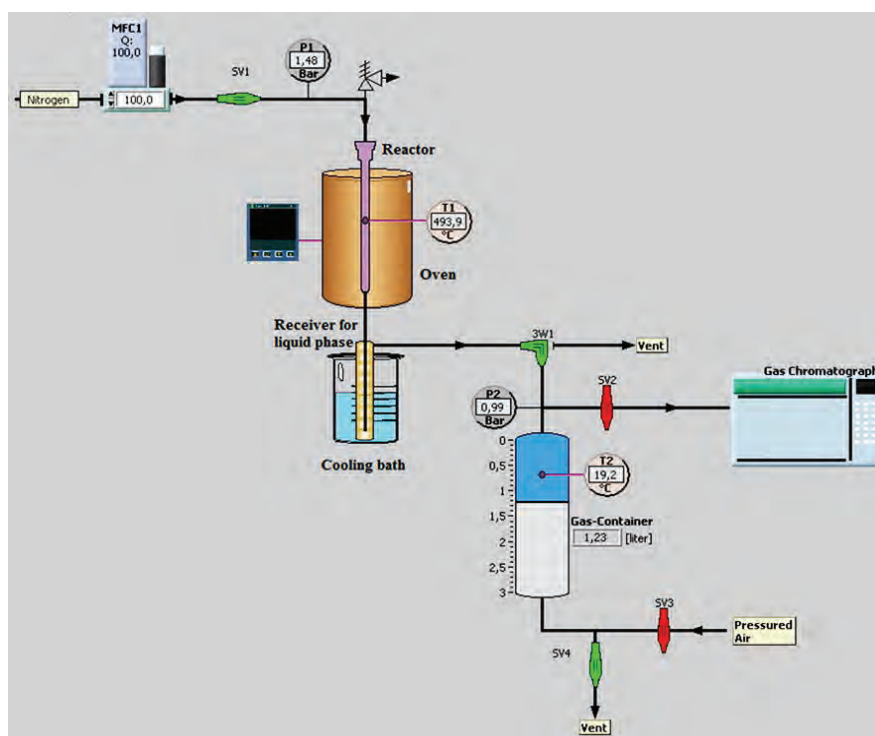


Fig. S-3. Experimental pyrolysis unit.

TABLE S-I. The influence of temperature on bio-oil yield

Temperature, K	Solid phase	Liquid phase	Gas phase
CaO/ZSM-5			
723	66.1	22.8	11.1
773	60.8	25.5	13.6
823	59.5	20.8	19.7
NiO/ZSM-5			
723	69.7	24.8	5.5
773	55.1	34.8	10.1
823	53.3	33.4	13.3

TABLE S-II. Composition of the organic phases (wt. % of the organic fraction) in bio-oil; $M > 164 \text{ g mol}^{-1}$ phenols were not found

Temp., K	Phenols	HCs	Acids/ esters	Alcohols/ ethers	Carbonyls/ aldehydes	PAHs	Phenyl propanoid
CaO/ZSM-5							
723	71.5	3.2	14.5	0.0	0.6	0.0	0.0
773	84.1	4.2	4.9	1.9	0.0	1.2	0.5
823	85.6	3.5	2.6	0.8	0.0	0.0	0.0
NiO/ZSM-5							
723	65.6	21.8	0.8	8.0	2.1	0.0	0.0
773	68.7	12.2	7.4	3.5	2.3	0.0	0.0
823	71.2	9.3	15.9	0.0	2.6	0.0	0.0

TABLE S-III. The influence of the MO content on bio-oil yield

Metal-oxide content, wt. %	Solid phase	Liquid phase	Gas phase
CaO/ZSM-5			
1	51.7	33.3	15.0
3	56.0	29.4	14.6
NiO/ZSM-5			
1	56.3	25.6	18.1
3	51.2	27.0	21.8

TABLE S-IV. Composition of the organic phase (wt. % of the organic fraction) in bio-oil; $M > 164 \text{ g mol}^{-1}$ phenols and PAHs were not found

Metal-oxide content, wt. %	Phenols	HCs	Acids/ esters	Alcohols/ ethers	Carbonyls/ aldehydes	Phenyl propanoid
CaO/ZSM-5						
1	60.5	30.9	0.0	5.8	1.8	0.0
3	69.5	6.7	14.4	3.0	1.7	0.4
NiO/ZSM-5						
1	56.8	21.7	6.7	8.7	1.0	0.0
3	61.4	16.3	7.4	6.2	1.2	0.0